US009481416B2

(12) **United States Patent**
Conaway et al.

(10) **Patent No.: US 9,481,416 B2**
(45) **Date of Patent: Nov. 1, 2016**

(54) **AUXILIARY AXLE AND SUSPENSION ASSEMBLY**

(71) Applicant: **SAF-HOLLAND, Inc.**, Holland, MI (US)

(72) Inventors: **Richard Conaway**, Grand Haven, MI (US); **Daniel R. Dykstra**, Grand Rapids, MI (US); **Marc Johnson**, Muskegon, MI (US); **Doug Thole**, Muskegon, MI (US); **Boyd Freeman**, Muskegon, MI (US)

(73) Assignee: **SAF-HOLLAND, Inc.**, Holland, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/616,055**

(22) Filed: **Feb. 6, 2015**

(65) **Prior Publication Data**

US 2015/0151801 A1 Jun. 4, 2015

Related U.S. Application Data

(63) Continuation of application No. 14/132,752, filed on Dec. 18, 2013, now Pat. No. 9,290,221.

(60) Provisional application No. 61/757,471, filed on Jan. 28, 2013.

(51) **Int. Cl.**
B62D 7/18 (2006.01)
B62D 61/12 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***B62D 61/125*** (2013.01); ***B60G 5/04*** (2013.01); ***B60G 9/02*** (2013.01); ***B60G 11/27*** (2013.01); ***B60G 11/28*** (2013.01); ***B62D 7/144*** (2013.01); ***B62D 7/18*** (2013.01); ***B62D 9/00*** (2013.01); ***B62D 13/06*** (2013.01);
(Continued)

(58) **Field of Classification Search**
CPC B60G 5/02; B60G 5/04; B60G 9/02; B60G 2200/314; B60G 2200/445; B60G 2202/152; B60G 2300/04; B60G 2206/50; B62D 7/144; B62D 7/18
USPC 280/86.5, 93.512, 124.116, 124.128, 280/124.157
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

1,828,425 A 10/1931 Matthews
1,932,340 A 10/1933 Goltry
(Continued)

OTHER PUBLICATIONS

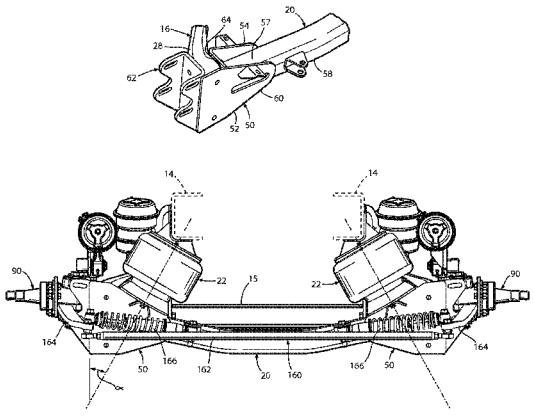
Ridewell Suspensions, Flex-Trac 232-8K Self-Steering Auxiliary Axle Suspension flyer.
(Continued)

Primary Examiner — James English
(74) *Attorney, Agent, or Firm* — Price Heneveld LLP

(57) **ABSTRACT**

A vehicle suspension assembly includes providing an axle assembly having a first end including a first mounting structure and a second end, providing a first bearing block and a second bearing block, forming a first aperture in the first bearing block and a second aperture in the second bearing block, attaching the first and second bearing blocks to the first mounting structure subsequent to forming the first and second apertures; and providing a first spindle assembly coupled to the first mounting structure by a first spherical bearing located within the first aperture and a second spherical bearing located within the second aperture, wherein a first kingpin assembly extends through the first and second spherical bearings, thereby coupling the first spindle with the first mounting structure.

24 Claims, 11 Drawing Sheets



(51) **Int. Cl.**

B60G 9/02	(2006.01)
B62D 7/14	(2006.01)
B62D 13/06	(2006.01)
B60G 5/04	(2006.01)
B60G 11/27	(2006.01)
B60G 11/28	(2006.01)
B62D 9/00	(2006.01)

(52) **U.S. Cl.**

CPC *B60G 2200/30* (2013.01); *B60G 2200/314* (2013.01); *B60G 2200/445* (2013.01); *B60G 2202/152* (2013.01); *B60G 2204/126* (2013.01); *B60G 2204/143* (2013.01); *B60G 2300/02* (2013.01); *B60G 2300/04* (2013.01); *Y10T 29/49622* (2015.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

3,191,954	A	6/1965	Schuetz
3,282,601	A	11/1966	Harbers
3,477,738	A	11/1969	Manning
4,079,798	A	3/1978	Ferris
4,171,830	A	10/1979	Metz
5,015,004	A	5/1991	Mitchell
5,090,495	A	2/1992	Christenson
5,230,528	A	7/1993	Van Raden et al.
5,303,946	A	4/1994	Youmans et al.
5,540,454	A	7/1996	VanDenberg et al.
5,549,322	A	8/1996	Hauri
5,597,174	A	1/1997	Christenson et al.
5,865,452	A	2/1999	Chalin
6,036,201	A	3/2000	Pond et al.
6,062,578	A	5/2000	Richardson
6,073,946	A	6/2000	Richardson
6,182,984	B1	2/2001	Chalin
6,213,647	B1	4/2001	Lin
6,247,713	B1	6/2001	Konop
6,398,236	B1	6/2002	Richardson
6,616,156	B1	9/2003	Dudding et al.
6,796,566	B2	9/2004	VanDenberg
6,808,189	B1	10/2004	Schlosser et al.
6,845,989	B2	1/2005	Fulton et al.
6,880,839	B2	4/2005	Keeler et al.
6,883,813	B2	4/2005	Gottschalk
6,902,176	B2	6/2005	Gottschalk
7,152,866	B2	12/2006	Chalin et al.
7,322,587	B2	1/2008	Chalin et al.
7,360,773	B2	4/2008	Gottschalk
7,530,583	B2	5/2009	Gottschalk
7,618,049	B2	11/2009	Varela et al.
7,845,658	B2	12/2010	Chalin et al.
7,862,058	B2	1/2011	Bubulka et al.
2004/0262874	A1	12/2004	Lorente
2005/0151337	A1	7/2005	Chalin et al.
2007/0040343	A1	2/2007	Chalin et al.
2008/0290723	A1	11/2008	Gottschalk
2011/0057406	A1	3/2011	Chalin et al.
2011/0079459	A1	4/2011	Gottschalk et al.
2011/0115184	A1	5/2011	Johnson et al.
2011/0163514	A1	7/2011	Saieg et al.

OTHER PUBLICATIONS

Ridewell Suspensions, Next Generation RUL-245 "Bantamweight" flyer.

Ridewell Suspensions, RSS-232-13K Flex-Trac web page, http://www.ridewellcorp.com/Web/Site.nsf/ID/RSS-232-135; printed May 27, 2010.

SAF-Holland, Inc., Steering Tag Axle Assembly drawing.

Otto Sauer Achsenfabrik GMBH; SAF Air Suspended Tag Axles for Commercial Vehicles brochure,Oct. 2005.

Link Mfg. Ltd., Duromax Roll Off (8A000705) Installations Instructions, Aug. 10, 2003.

Link Mfg. Ltd., 8A000715 Duralift II Installation Instructions, Oct. 2, 2009.

Link Mfg. Ltd., Model 5500 Installation Instructions, Jan. 6, 2014.

Link Mfg. Ltd., 20K Duralift II Installation Instructions, Oct. 3, 2009.

Link Mfg. Ltd., Duramax (8A000450) Installation Instructions, Aug. 10, 2013.

Link Mfg. Ltd., Model 6000 for Roll-Off Applications Installation Instructions, Apr. 11, 2005.

Link Mfg. Ltd., Model 6000 Installation Instructions, Jan. 4, 2014.

Watson & Chalin, Mfg., AL-1200/1600/1900DB Series High Lift Non-Steerable Tag Lift Axle flyer.

Watson & Chalin, Mfg., AL-1300 Series Non-Steerable Lift Axle flyer.

Watson & Chalin, Mfg., AL-2200 Series Non-Steerable Lift Axle flyer.

Watson & Chalin, Mfg., AL-2300 Series Non-Steerable Lift Axle flyer.

Watson & Chalin, Mfg., AL-800 Series Non-Steerable Lift Axle Suspenion flyer.

Watson & Chalin, Mfg., RSL-1186TT Reverse Steer Tru-Track flyer.

Watson & Chalin, Mfg., SL-0890 Series Tru-Track Super Alumilite flyer.

Watson & Chalin, Mfg., SL-0893 Series Tru-Track Super Alumilite flyer.

Watson & Chalin, Mfg., SL-1093 10K Tru-Track Alumilite flyer.

Watson & Chalin, Mfg., SL-1152TT RO Tru-Track Series flyer.

Watson & Chalin, Mfg., SL-1185TTHL Self-Steering Axle & Suspension System web page, http://www.watsonsuspensions.com/prods/series.php?p=51, printed Oct. 16, 2010.

Watson & Chalin, Mfg., SL-11877TT Tru-Track Series flyer.

Watson & Chalin, Mfg., SL-1188 Series Tru-Track Lite flyer.

Watson & Chalin, Mfg., SL-1190TT Series Tru-Track Alumilite flyer.

Watson & Chalin, Mfg., SL-1193 THL Hydraulic Tag Lift Axle flyer.

Watson & Chalin, Mfg., SL-2055 20K Tru-Track flyer.

Watson & Chalin, Mfg., SL-2089TT Series 20K Tru-Track flyer.

Watson & Chalin, Mfg., Tru-Track Series Steerable Axle Lift Suspension, Installation and Operation Manual, 2003.

Silent Drive, Inc., Maxle DB Hydraulic Raise & Lower Air Ride Suspension, Nov. 27, 2005. vol. 1.

Silent Drive, Inc., AAS-770 Air Suspension Self-Steering, Nov. 27, 2005, vol. 1.

Silent Drive, Inc., Tag & Pusher Axles Application Charts, 2006.

Silent Drive, Inc., AAS-747-13FA Series Air Suspension, Mar. 12, 2008, vol. 1.

Silent Drive, Inc., AAS-747-8 Series Air Suspension, Mar. 12, 2008, vol. 1.

Silent Drive, Inc., AAS-747-12 Series Air Suspension, Mar. 12, 2008, vol. 1.

Silent Drive, Inc., AAS-747-13 Series Air Suspension, Mar. 12, 2008, vol. 1.

Silent Drive, Inc., AAS-737-20 Series Parallelogram Air Suspensions, Nov. 27, 2005, vol. 1.

Silent Drive, Inc., AAS-740 Series Parallelogram Air Suspension, Nov. 27, 2005, vol. 1.

Silent Drive, Inc., More Features . . . More Benefits.

Silent Drive, Inc., AA-115 Air Suspension Non-Steer flyer, Nov. 27, 2005, vol. 1.

Silent Drive, Inc., AA-135 High Lift Air Suspension Non-Steer flyer, Nov. 27, 2005, vol. 1.

Silent Drive, Inc., AA-1355 Series Air Suspensions Non-Steer flyer, Nov. 27, 2005, vol. 1.

Silent Drive, Inc., AA-1455 Air Suspension Non-Steer flyer, Nov. 27, 2005, vol. 1.

Silent Drive, Inc., AA-230-INB Series Air Lift Air Suspension Non-Steer flyer, Nov. 27, 2005, vol. 1.

Silent Drive, Inc., AAS-240 Series, Air Suspension Self-Steering flyer, Nov. 27, 2005, vol. 1.

(56) **References Cited**

OTHER PUBLICATIONS

Silent Drive, Inc., AA-270 Air Suspension Non-Steer flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AA-270-FD Air Suspension Non-Steer Drop Axle flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AAS-114 Series Self-Steering Air-Suspension flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AAS-115 Air Suspension Self-Steering flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AAS-1355 Air Suspension Self-Steering flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AAS-713 Air Suspension Self-Steering flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AAS-721 Series Parallelogram Air Suspension flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AAS-721-FA Series Parallelogram Air Suspension flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AAS-724 Series Parallelogram Air Suspension flyer, Nov. 27, 2005, vol. 1.
Silent Drive, Inc., AAS-727-SH Series Parallelogram Air Suspension flyer, Nov. 27, 2005, vol. 1.
Hendrickson, Lift Axles Full Line of Auxiliary Lift Axles brochure, Mar. 2009.
Hendrickson, HLM-2 Series Specifications brochure, Jan. 2006.
Hendrickson, HLN Series Specifications brochure, Aug. 2002.
Hendrickson, HLN Paralift Fixed Axle Suspension System web page, http://www.hendrickson-intl.com/products/product_detail/hln_paraliftasp, printed Oct. 27, 2010.
Hendrickson, HLR-2 Series Non-steer Lift Axle Systems brochure; Feb. 2003.
Hendrickson, HLR-3 Fixed Axle Suspension System web page, http://www.hendrickson-intl.com/products/prodcut_detail/hlr_3.asp, printed Oct. 26, 2010.
Hendrickson, Paralift Steerable Suspension System brochure, Feb. 2009.
Hendrickson, Composilite ST Composilite STS Specifications brochure, Jun. 2005.
Hendrickson, Pararev—Next Generation Technology flyer.
Hendrickson, Composilite FBC Light-duty Steerable for Federal Bridge Formula Compliance brochure, Jan. 2007.
Hendrickson, Composilite FX Fixed-axle Suspension System brochure, Mar. 2004.
Hendrickson, Composilite RO for Roll-off Applications brochure, Apr. 2008.
Hendrickson, Composilite SC Family of Steerable Lift Axles brochure, Feb. 2010.
Hendrickson, Composilite ST Steerable Lift Axle System brochure, Mar. 2007.
Hendrickson, HLUR-2 PARAREV Specifications, Dec. 2004.
Hendrickson, Reverse Steerable Suspension System Technical Procedures manual, Aug. 2002.
Hendrickson, PARAREV Integrated Reverse Castor, Steel Axle System flyer.
Hendrickson, TLA Series Tag Lift Axle flyer.
Reyco Granning Suspensions, MaxiMiser Series Model L132LW Light Weight Parallelogram Suspension with Self-Steering Axles Specification Sheet, Sep. 9, 2004.
Reyco Granning Suspensions, Model L225 Lift Air Ride Air Lift Suspension Specification Sheet, Aug. 20, 2004.
Reyco Granning Suspensions, Model T200AX Extra-High Lift Air Ride Air Lift Suspensions Specification Sheet, Aug. 20, 2004.
Ridewell Suspensions, RCA-215 Flex-Mount Non-Steerable Auxiliary Axle Suspension flyer.
Ridewell Suspensions, Flex-Trac 232-13K Self-Steering Auxiliary Axle Suspension flyer.
Ridewell Suspensions, Flex-Trac 232-20K Self-Steering Auxiliary Axle Suspension flyer.

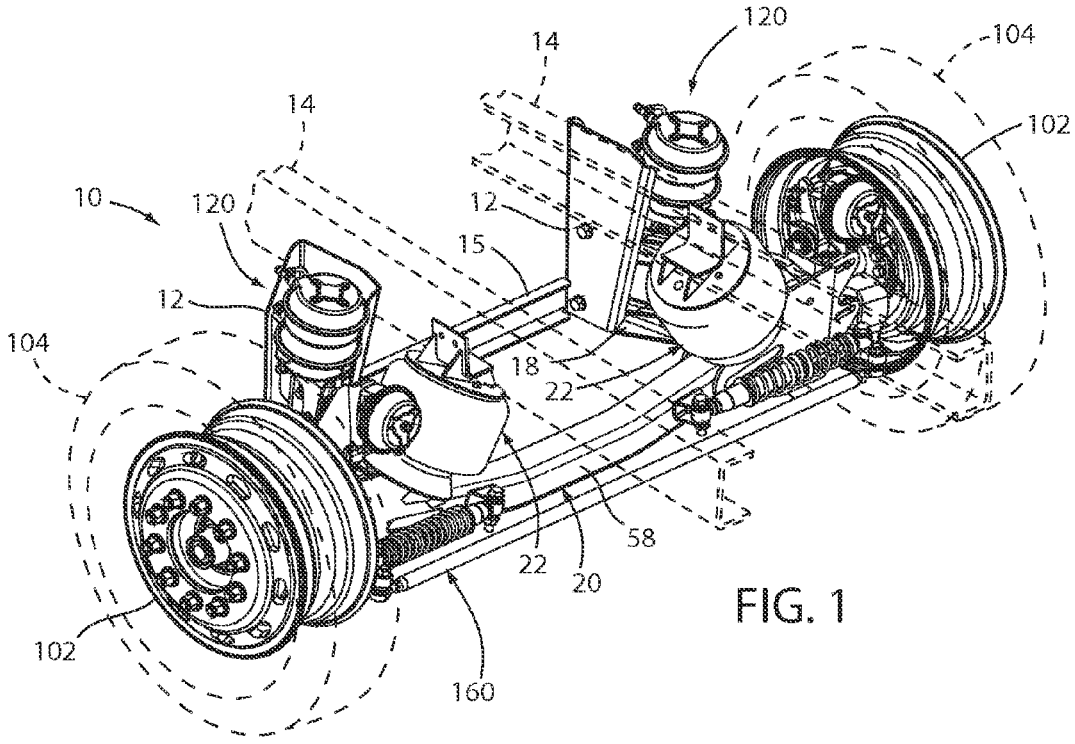

120
14
104
14
102
10
120
12
15
12
104
18
22
22
58
20
102
160

FIG. 1

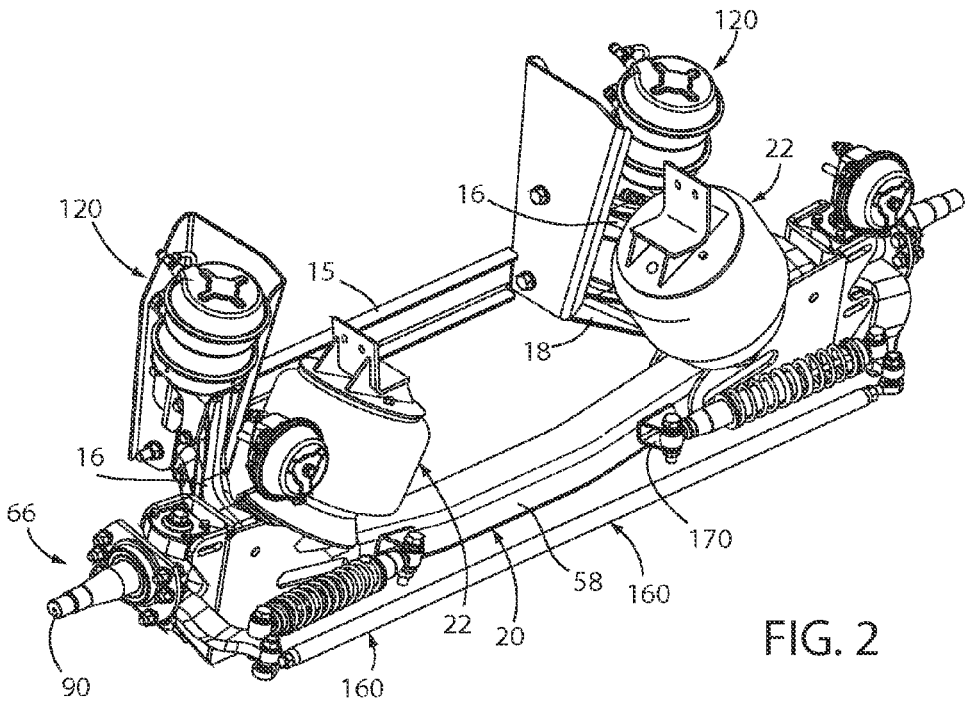

120
22
16
120
15
18
16
66
170
58
160
22
20
90
160

FIG. 2

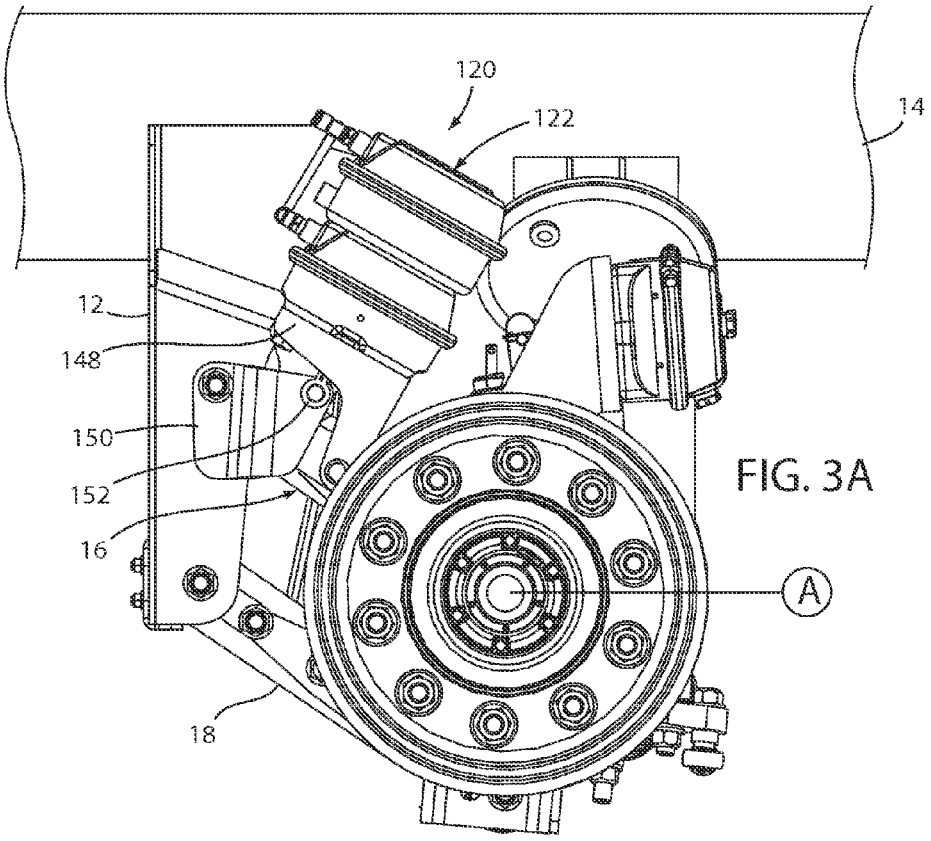

120
122
14
12
148
150
152
16
A
18

FIG. 3A

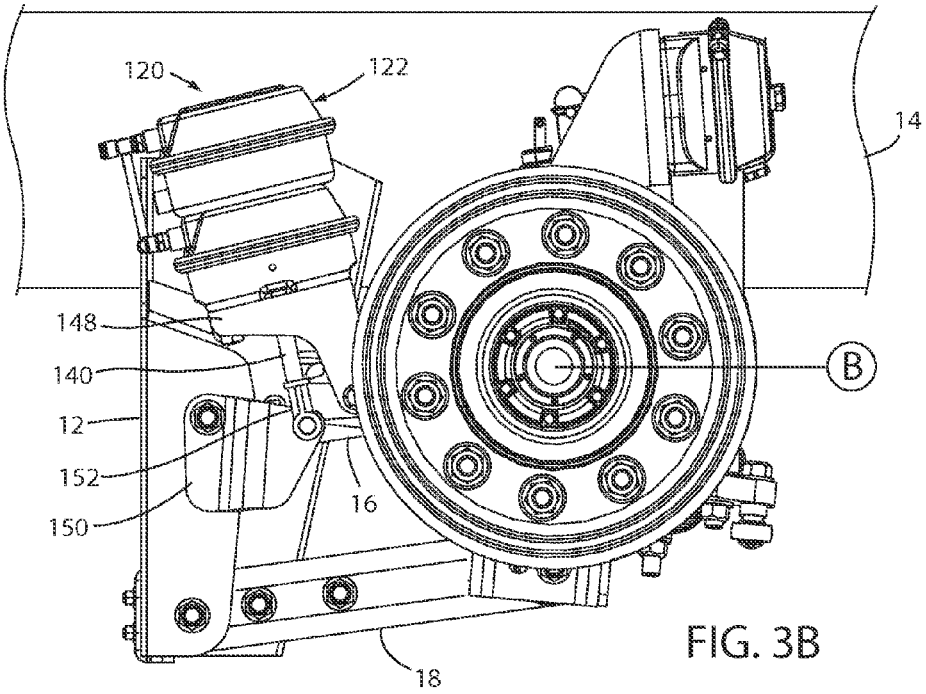

120
122
14
148
140
12
152
150
16
B
18

FIG. 3B

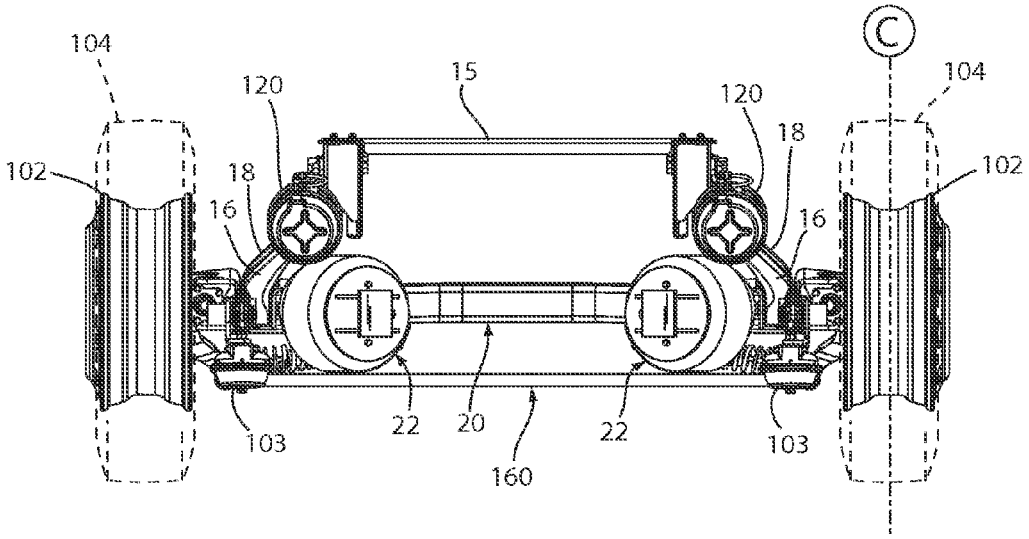

C
104
120
15
120
104
102
18
18
102
16
16
22
20
22
103
103
160

FIG. 4A

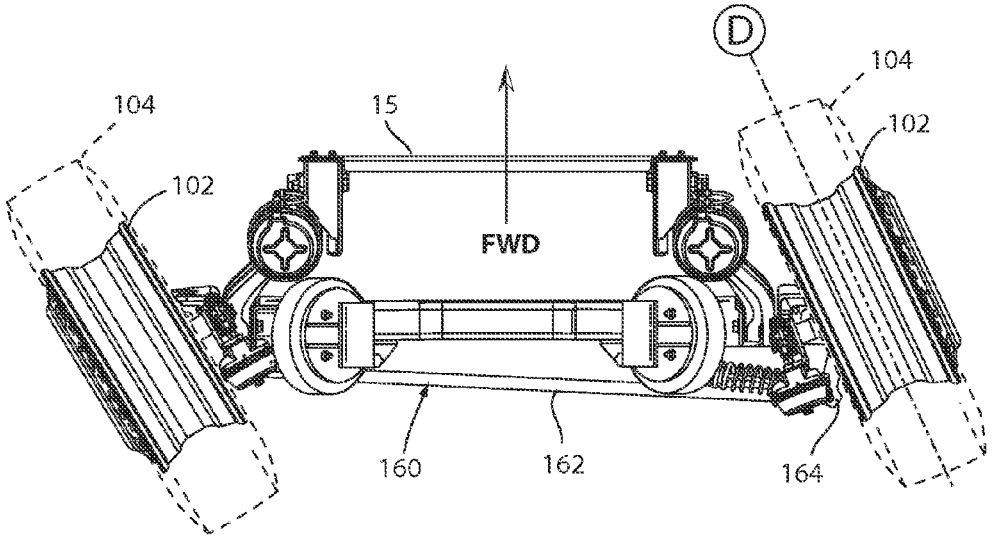

D
104
104
15
102
102
FWD
160
162
164

FIG. 4B

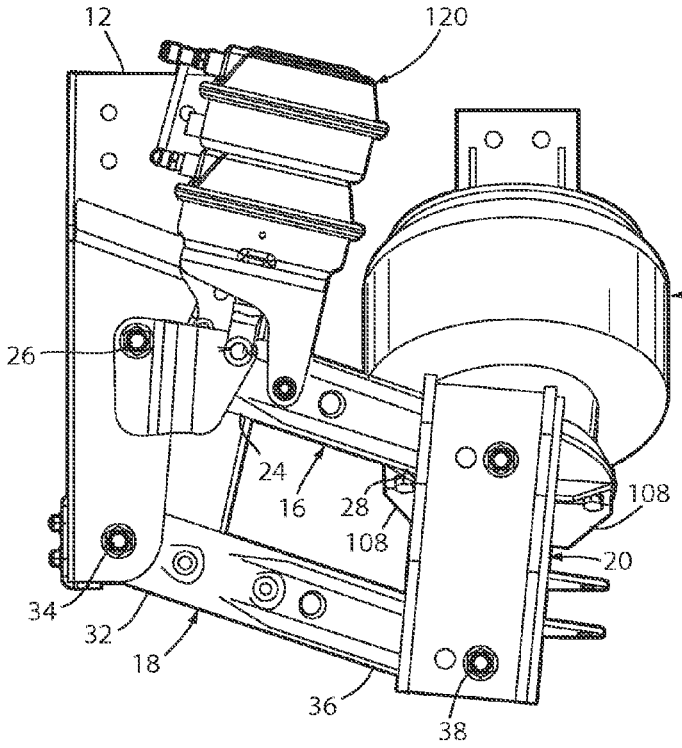


FIG. 5

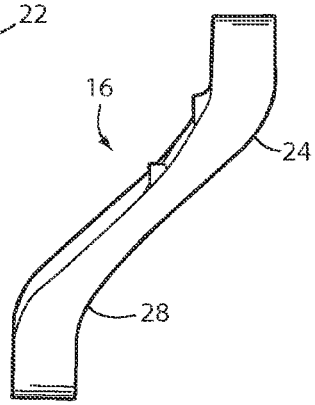


FIG. 6

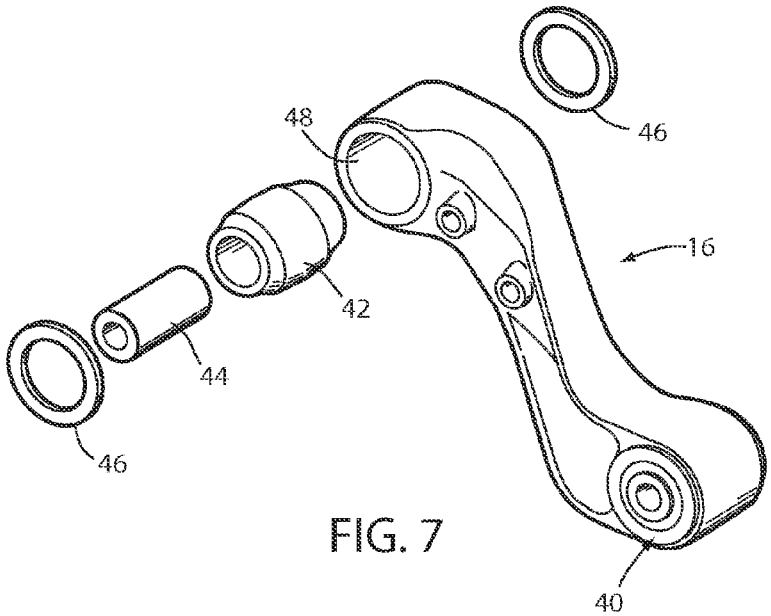


FIG. 7

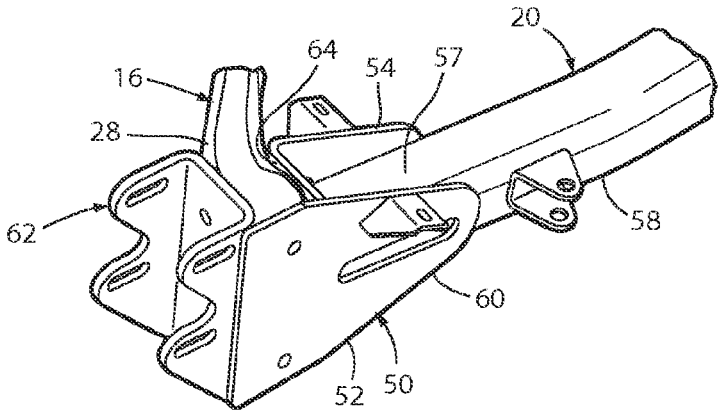


FIG. 8

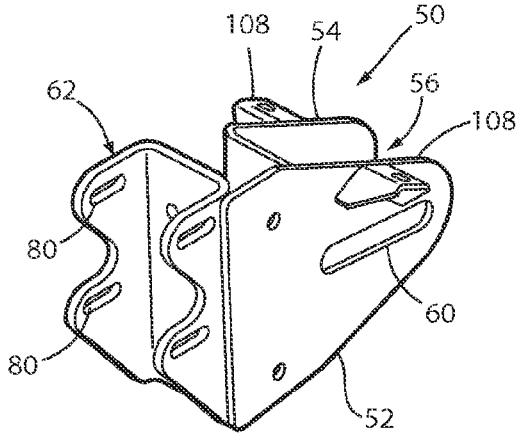


FIG. 9A

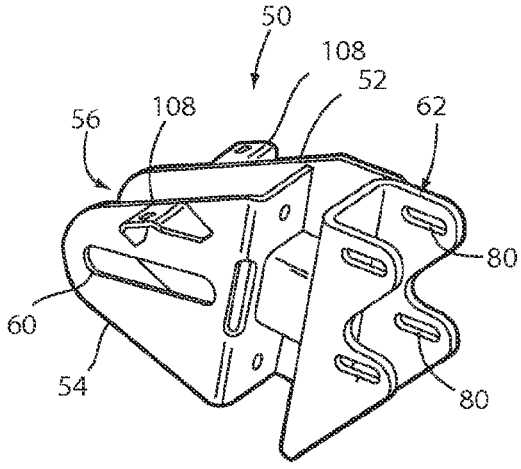


FIG. 9B

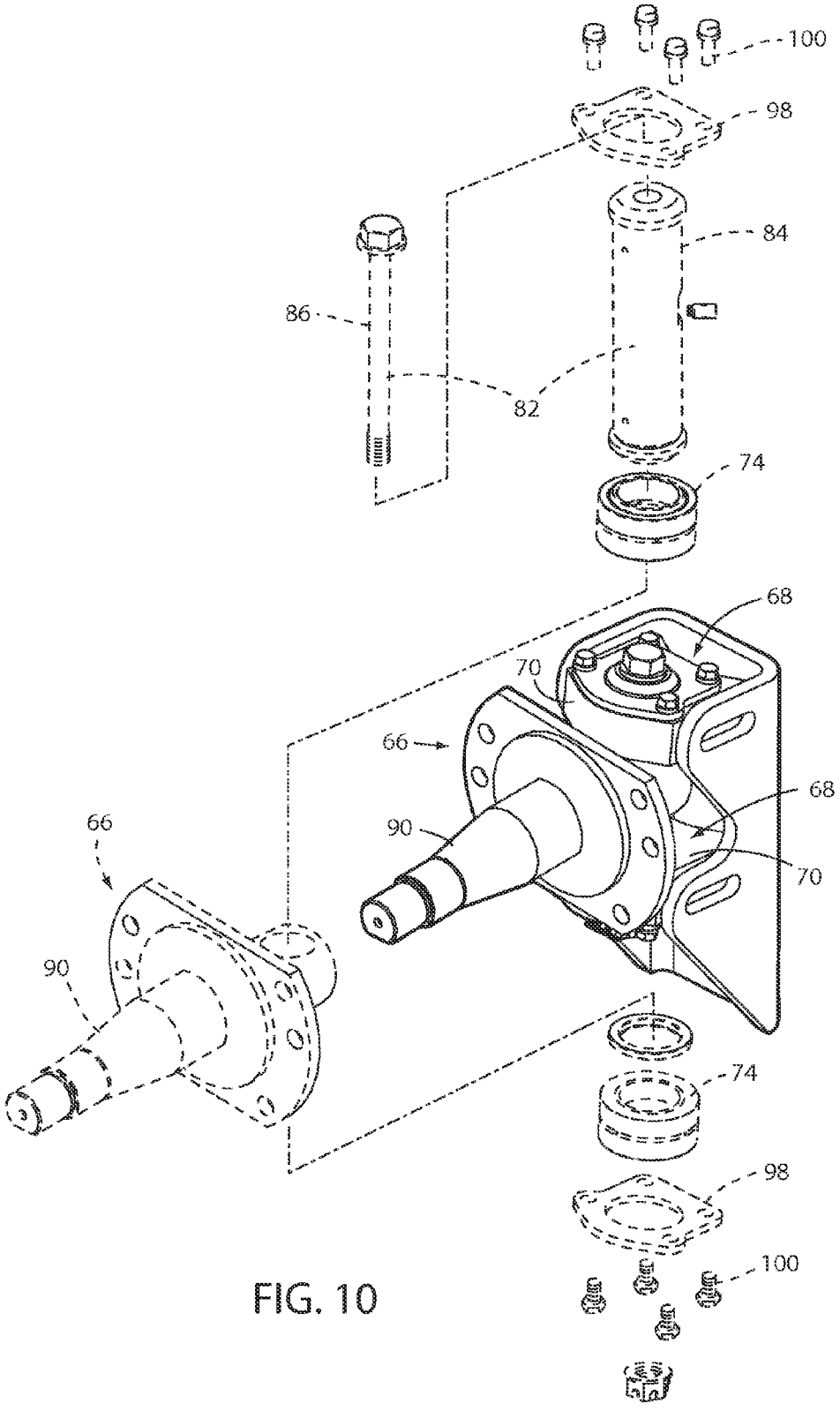


FIG. 10

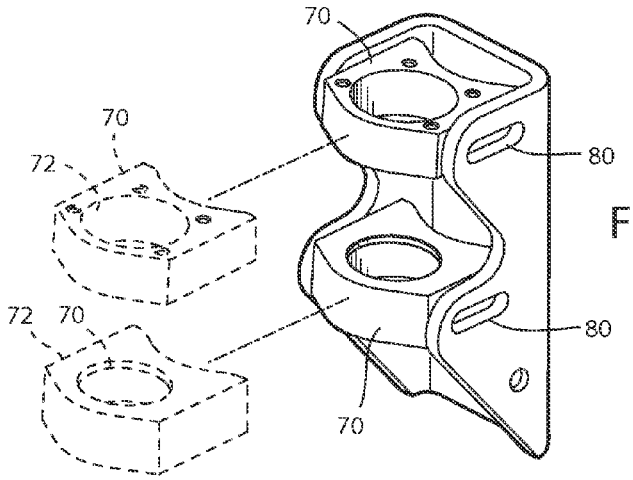


FIG. 11

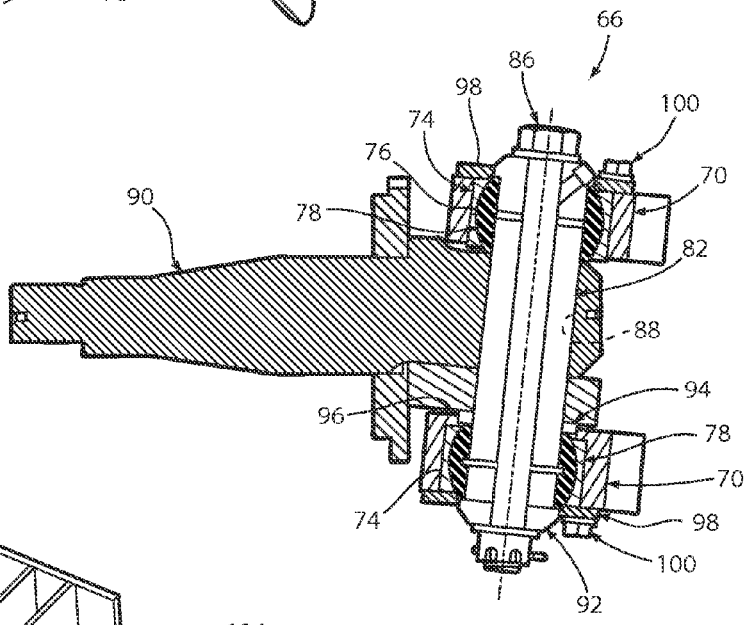


FIG. 12A

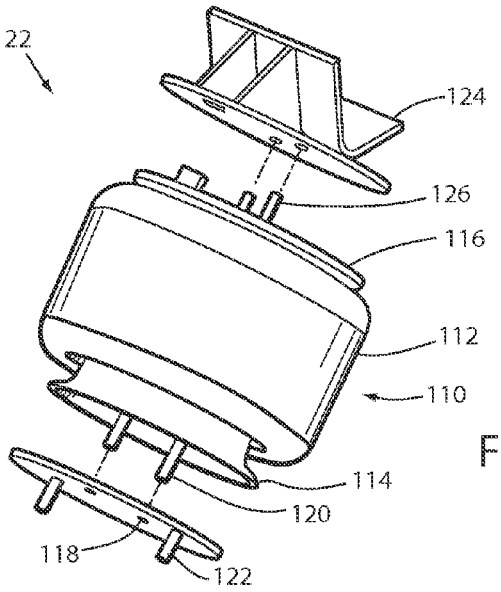


FIG. 13

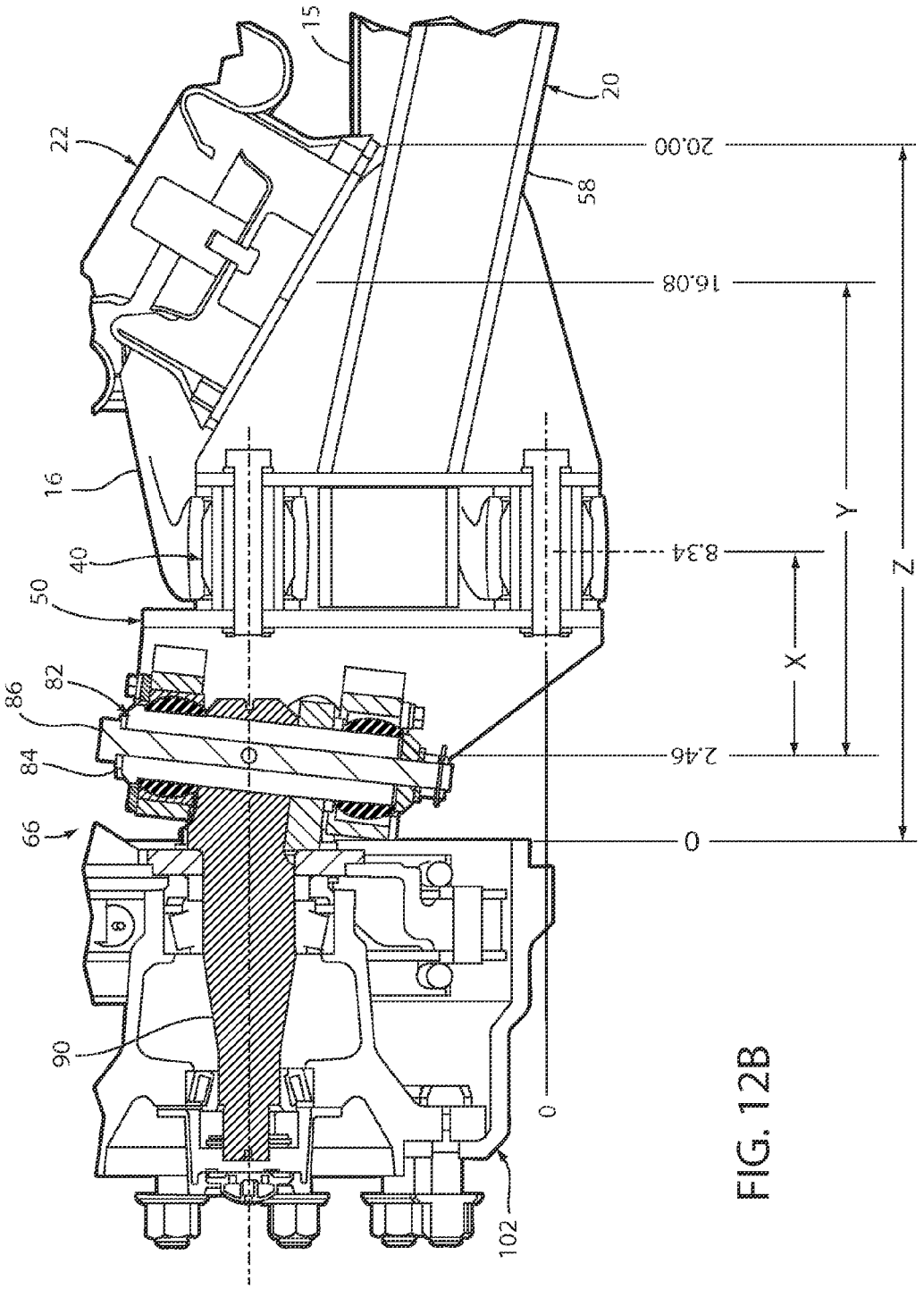


FIG. 12B

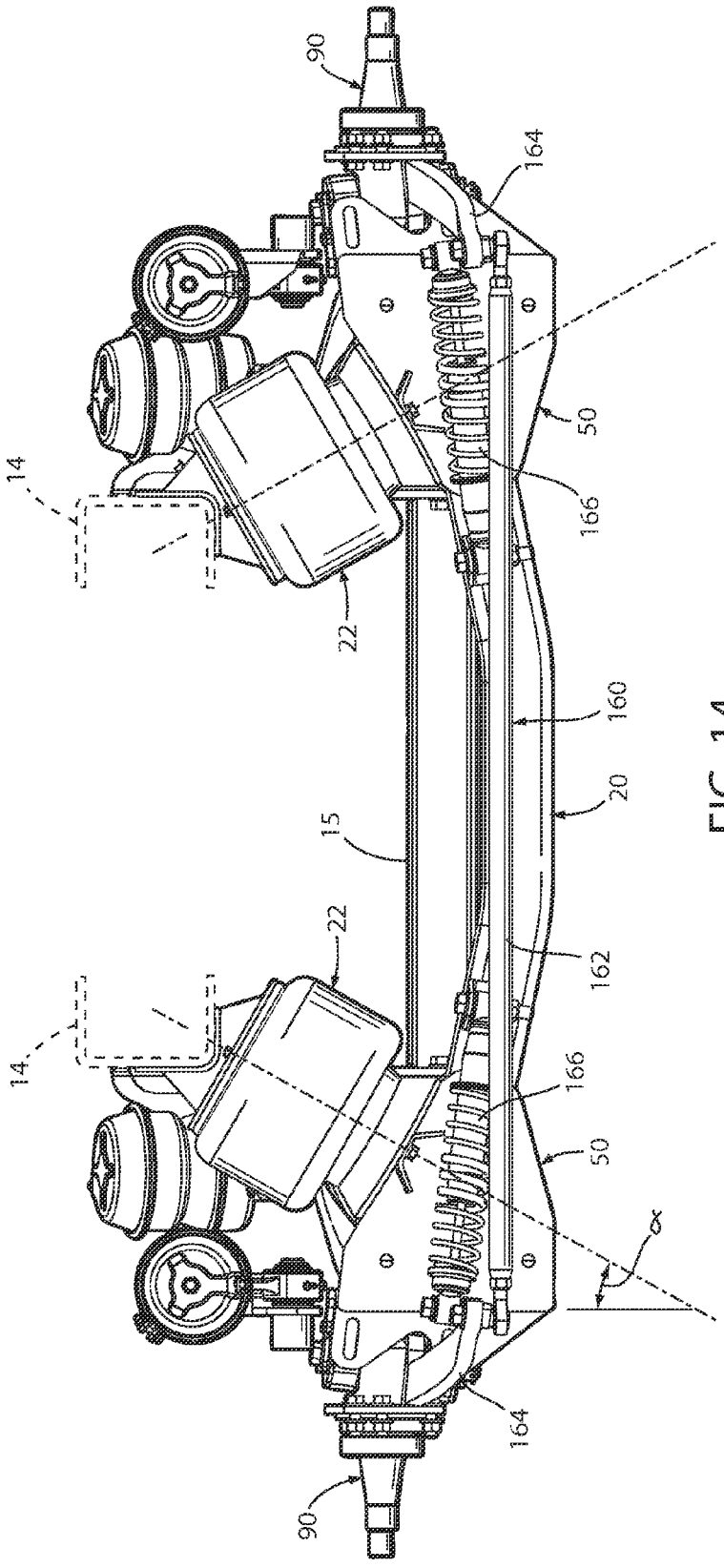


FIG. 14

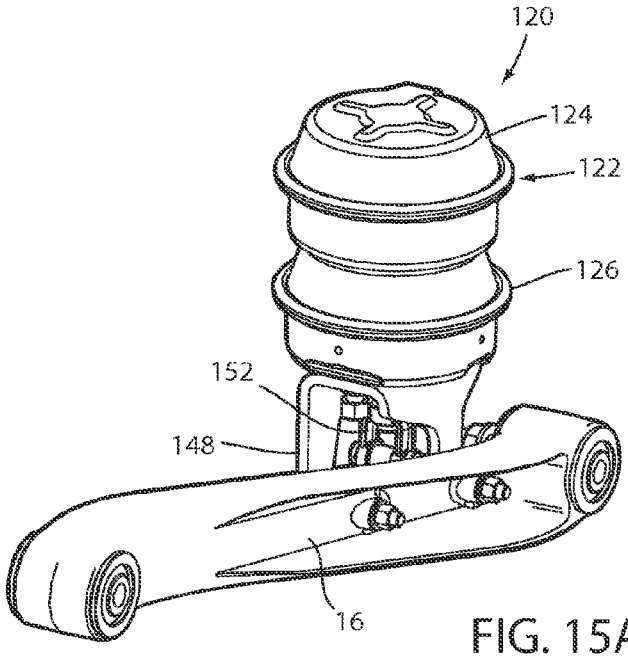


FIG. 15A

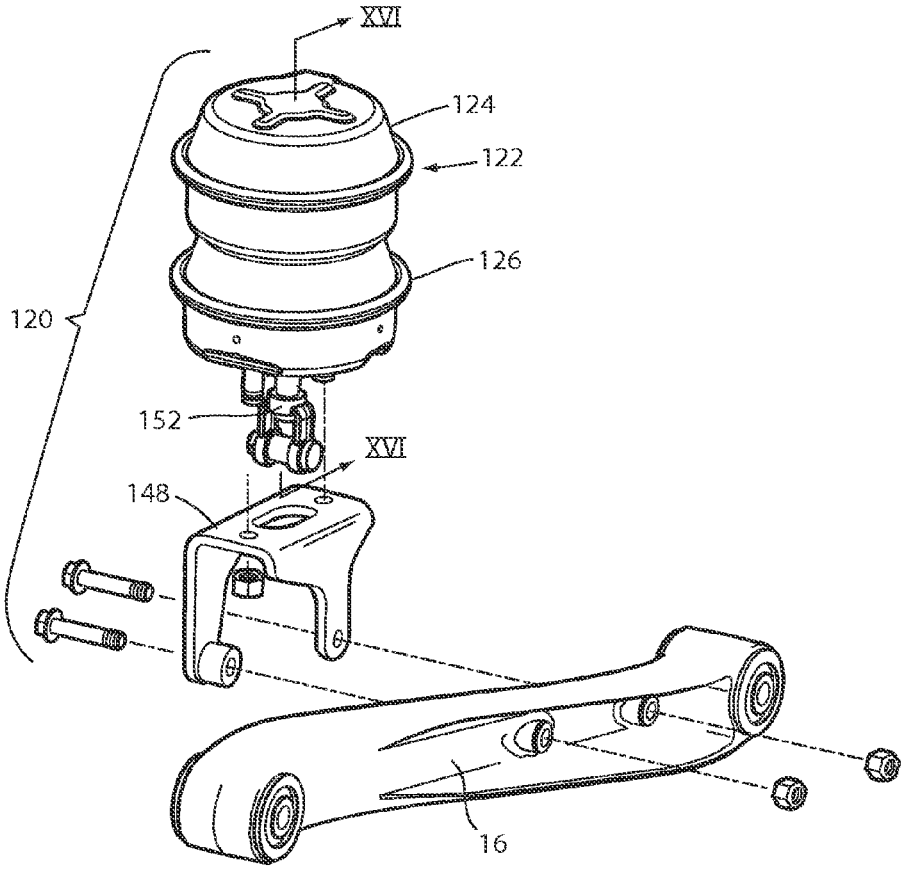


FIG. 15B

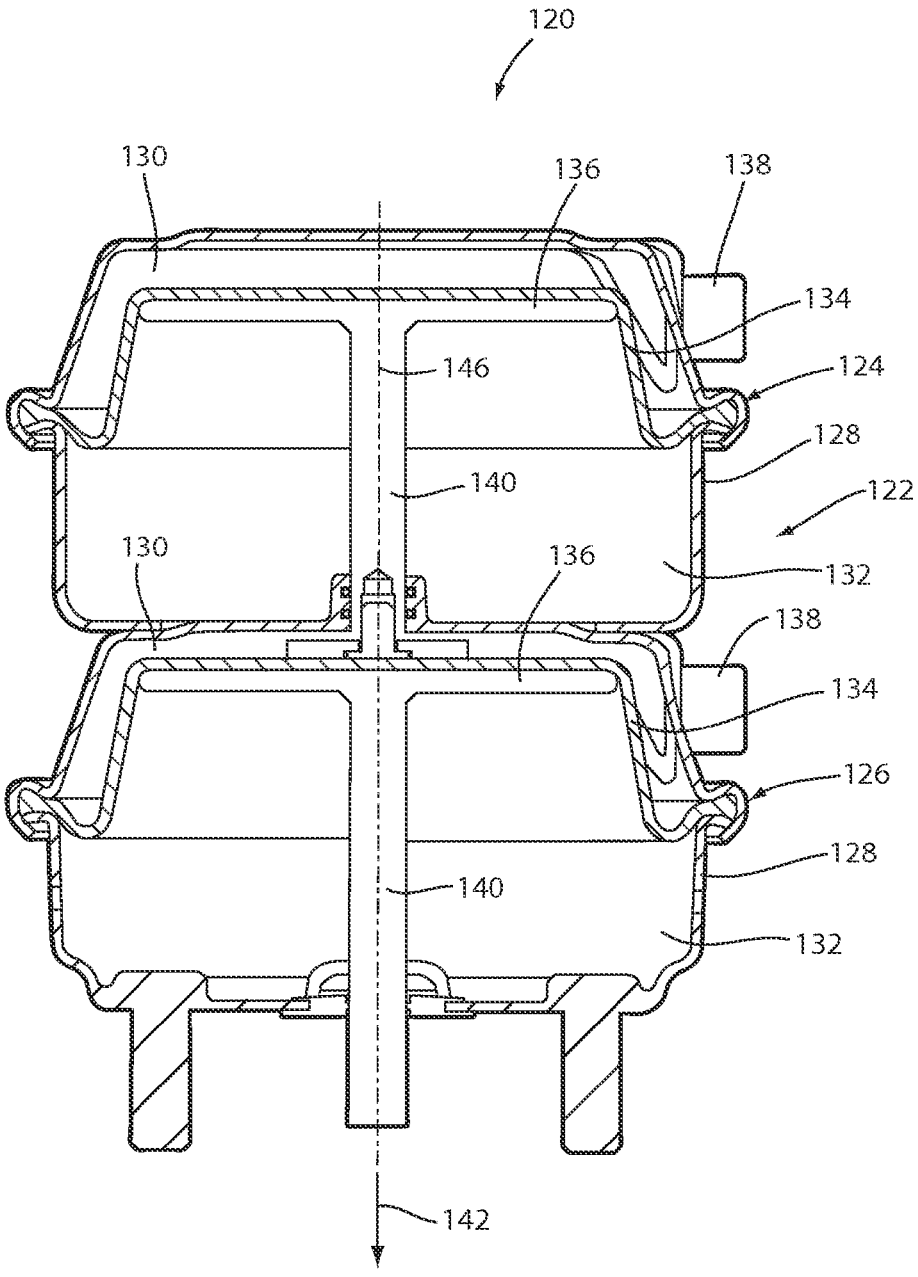

120
130
136
138
134
146
124
128
140
122
130
136
132
138
134
126
128
140
132
142

FIG. 16

AUXILIARY AXLE AND SUSPENSION ASSEMBLY

BACKGROUND OF THE INVENTION

The present invention relates to heavy duty vehicle suspensions and assemblies, and particularly to suspension assemblies incorporating a trailing arm-type configuration. More particularly, the present invention relates to an auxiliary vehicle suspension assembly adapted for movement between an in-use position and a storage position, and incorporating a self-steer assembly.

BRIEF SUMMARY OF THE INVENTION

One aspect of the present invention is to provide a method of assembling a vehicle suspension assembly comprising providing an axle assembly having a first end including a first mounting structure and a second end, providing a first bearing block and a second bearing block, forming a first aperture in the first bearing block and a second aperture in the second bearing block, attaching the first and second bearing blocks to the first mounting structure subsequent to forming the first and second apertures, and providing a first spindle assembly coupled to the first mounting structure by a first spherical bearing located within the first aperture and a second spherical bearing located within the second aperture, wherein a first kingpin assembly extends through the first and second spherical bearings, thereby coupling the first spindle with the first mounting structure.

Another aspect of the present invention is to provide a vehicle suspension assembly that comprises an axle member having a first end and a second end, a first mounting bracket adapted to couple to a vehicle frame assembly, a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the axle member, a second mounting bracket adapted to couple to the vehicle frame assembly, and a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the axle member. The vehicle suspension assembly further comprises an integral, one-piece first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement couples the first end of the axle member to a first spindle assembly, and wherein the first mounting arrangement couples the first air spring to the first end of the axle member such that the first air spring is adapted to extend between the first end of the axle member and the vehicle frame assembly, and an integral, one-piece second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement couples the second end of the axle member to a second spindle assembly, and wherein the second mounting arrangement couples a second air spring to the second end of the axle member such that the second air spring is adapted to extend between the second end of the axle member and the vehicle frame assembly.

Still another aspect of the present invention is to provide a vehicle suspension assembly that comprises an axle member having a first end and a second end, a first mounting bracket adapted to couple to a vehicle frame assembly, a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end, a second mounting bracket adapted to couple to the vehicle frame assembly, and a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end. The vehicle suspension assembly further comprises an integrated first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement couples the first end of the axle member to a first spindle assembly, and wherein the first mounting arrangement couples the first air spring to the first end of the axle member such that the first air spring is adapted to extend between the first end of the axle member and the vehicle frame assembly, wherein the first mounting arrangement couples the second end of the first trailing arm to the first end of the axle member at a first location, the first spindle to the first end of the axle member at a second location, and the first air spring to the first end of the axle member at a third location, and wherein a maximum distance between any one of the first location, the second location and the third location is less than or equal to about 14 inches, and an integrated second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement couples the second end of the axle member to a second spindle assembly, and wherein the second mounting arrangement couples a second air spring to the second end of the axle member such that the second air spring is adapted to extend between the second end of the axle member and the vehicle frame assembly, wherein the second mounting arrangement couples the second end of the second trailing arm to the second end of the axle member at a fourth location, the second spindle to the second end of the axle member at a fifth location, and the second air spring to the second end of the axle member at a sixth location, and wherein a maximum distance between any one of the fourth location, fifth location and sixth location is less than or equal to about 14 inches.

Still yet another aspect of the present invention is to provide a vehicle suspension assembly that comprises an axle member having a first end and a second end, a first mounting bracket adapted to couple to a vehicle frame assembly, a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end, a second mounting bracket adapted to couple to the vehicle frame assembly, and a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end. The vehicle suspension assembly further comprises an integrated first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement couples the first end of the axle member to the second end of the first trailing arm, a first spindle assembly, and a first air spring such that the first air spring is adapted to extend between the first end of the axle member and the vehicle frame assembly, and wherein the first mounting arrangement has a total length of less than or equal to about 20 inches, and an integrated second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement couples the second end of the axle member to the second end of the second trailing arm, a second spindle assembly, and a second air spring such that the second air spring is adapted to extend between the second end of the axle member and the vehicle frame assembly, and wherein the second mounting arrangement has a total length of less than or equal to about 20 inches.

The present inventive vehicle suspension assembly provides a durable, uncomplicated design that can be easily and quickly assembled, while simultaneously reducing manufacturing costs. The invention is efficient in use, economical to manufacture, capable of a long operating life, and is particularly well adapted to the proposed use.

These and other advantages of the present invention will be further understood and appreciated by those skilled in the art by reference to the following written specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of a vehicle suspension assembly embodying the present invention;

FIG. **2** is a perspective view of the vehicle suspension assembly with wheel and hub assemblies removed;

FIG. **3**A is a side elevational view of the vehicle suspension assembly in a lowered, in-use position;

FIG. **3**B is a side elevational view of the vehicle suspension assembly in a raised, storage position;

FIG. **4**A is a top plan view of the vehicle suspension assembly in an inline orientation;

FIG. **4**B is a top plan view of the vehicle suspension assembly in a turning orientation;

FIG. **5** is a side elevational view of the suspension assembly;

FIG. **6** is a top plan view of a trailing arm;

FIG. **7** is an exploded perspective view of a trailing arm assembly;

FIG. **8** is an exploded perspective view of mounting arrangement and associated connections;

FIG. **9**A is a perspective rear view of the mounting arrangement;

FIG. **9**B is a perspective front view of the mounting arrangement;

FIG. **10** is an exploded perspective view of a spindle assembly, wherein the components of the spindle assembly are shown in dashed in an exploded state and in solid in an assembled state;

FIG. **11** is an exploded perspective view of bearing blocks and a portion of the mounting arrangement, wherein the bearing blocks are shown in dashed in the exploded state and in solid in an assembled state;

FIG. **12**A is a cross-sectional view of the spindle assembly and a portion of the mounting arrangement;

FIG. **12**B is a cross-section view of the vehicle suspension assembly;

FIG. **13** is an exploded perspective view of an air spring assembly;

FIG. **14** is a rear elevational view of the suspension assembly;

FIG. **15**A is a perspective view of a lift arrangement;

FIG. **15**B is an exploded perspective view of the lift arrangement; and

FIG. **16** is a cross-section view of a dual diaphragm actuator, taken along the line XVI-XVI, FIG. **15**.

DETAILED DESCRIPTION OF EMBODIMENTS

For purposes of description herein, the terms "upper," "lower," "right," "left," "rear," "front," "vertical," "horizontal," and derivatives thereof shall relate to the invention as oriented in FIG. **1**. However, it is to be understood that the invention may assume various alternative orientations, except where expressly specified to the contrary. It is also to be understood that the specific devices and processes illustrated in the attached drawings, and described in the following specification are simply exemplary embodiments of the inventive concepts defined in the appended claims. Hence, specific dimensions and other characteristics relating to the embodiments disclosed herein are not to be considered as limiting, unless the claims expressly state otherwise.

A suspension assembly **10** (FIGS. **1** and **2**) comprises a pair of mounting brackets **12** fixedly connected to a pair of longitudinally extending frame members **14** of a vehicle frame assembly and coupled to one another by a cross member **15**, a plurality of trailing arm assemblies including a pair of upper trailing arms **16** (FIGS. **3**A-**4**B) and a pair of lower trailing arms **18**, an axle assembly **20**, and a pair of air spring assemblies **22** extending between the axle assembly **20** and corresponding frame members **14**.

In the illustrated example, each upper trailing arm **16** (FIG. **5**) includes a first end **24** pivotably coupled to one of the mounting brackets **12** for rotation about a pivot point **26** and a second end **28** pivotably coupled to the axle assembly **20** for rotation about a pivot point **30**, as described below. Each lower trailing arm **18** includes a first end **32** pivotably secured to a mounting bracket **12** for pivoting about a pivot point **34**, and a second end **36** pivotably coupled to the axle assembly **20** for pivotable movement around a pivot point **38**, also as described below. FIGS. **4**A and **6** illustrate the generally outward-sweeping shape of the trailing arms **16**, **18** along the length of the trailing arms **16**, **18** from the first end **24**, **32** to the second end **28**, **36**. As best illustrated in FIG. **7**, each end **24**, **28**, **32**, **36** of the trailing arms **16**, **18** are pivotably secured to the mounting brackets **12** and axle assembly **20** by a bushing assembly **40** comprising a elastically resilient bushing member **42**, a bushing pin **44** and nylon washers **46** received within a corresponding bore **48**.

As best illustrated in FIG. **8**, the second end **28**, **36** of each trailing arm **16**, **18** are pivotably coupled to an integrated corresponding mounting arrangement **50**. Each mounting arrangement **50** (FIGS. **9**A and **9**B) includes a triangularly-shaped rear plate **52**, an L-shaped front plate **54** that cooperates with the rear plate **52** to form an inwardly-opening pocket **56** within which an end **57** of an axle member **58** of the axle assembly **20** is received. The rear plate **52** and the front plate **54** each include a welding aperture **60** about which a weld is formed to secure the end **57** of the axle **58** within the pocket **56**. Each mounting arrangement **50** further includes a C-shaped spindle attachment plate **62** that is attached to the rear plate **52**, and which cooperates with the rear plate **52** and the front plate **54** to form a pocket **64** within which the second ends **28**, **36** of the trailing arms **16**, **18** are pivotably secured. As utilized herein, the term "integrated" means that the components of the mounting arrangement **50**, including the rear plate **52**, the front plate **54** and the spindle attachment plate **62** are brought together with one another such that the components form a single unit and are not spaced from one another. In the illustrated example, the rear plate **52**, the front plate **54** and the spindle attachment **62** are welded to one another, however these components may also be formed as a single integral piece, or coupled together with various mechanical fasteners. Spindle assemblies **66** (FIGS. **2** and **10**-**12**A) are pivotably secured to the corresponding mounting arrangement **50** of the axle assembly **20** by a pair of bearing assemblies **68** each including a bearing block **70** having a bearing bore **72** that receives a corresponding bearing **74**, each bearing **74** including a race **76** and a spherical bearing member **78**. The spindle attachment plate **62** includes a plurality of elongated welding apertures **80** about which a weld is received to weld the bearing blocks **70** to the spindle attachment plate **62** of the mounting arrangement **50**. It is noted that the bearing bore **72** of each of the bearing blocks **70** is machined prior to attaching the bearing block **70** to the mounting arrangement **50**. A kingpin assembly **82** including an elongated kingpin collar **84** and a kingpin **86** extends through the bearings **74** and an aperture **88** of the spindle **90**, thereby pivotably securing the spindle **90** to the axle assembly **20**. Specifically, tightening of the kingpin **86** creates a load path extending through the kingpin collar **84**, each of the spherical bearing members **78**, an end of the spindle **90**, and a collar member **92**. Over-tightening of the kingpin **86** is

prevented by a washer member **94** positioned between the lower of the spherical bearing members **78** and the spindle **90**. It is noted that the lower of the bearing blocks **70** includes a collar portion **96** that abuts the race **76** of the corresponding bearing **74**, thereby providing proper spacing and assisting during assembly. Specifically, the collar portion or lip **96** provides a stop for the bearing to be pressed to during assembly, thereby defining the vertical positioning for the entire spindle assembly. Further, the lip **96** is adapted to support the vertical load should the press-fit of the bearing fail. A pair of retainer plates **98** are secured to the corresponding bearing blocks **70** by a plurality of bolts **100**. The hub assemblies **102**, breaking assemblies **103** and tires **104** are coupled to the associated spindle **90**.

Each mounting arrangement **50** (FIGS. **9**A and **9**B) includes forwardly and rearwardly extending air spring mounting brackets **108** to which the corresponding air spring assembly **22** (FIG. **5**) is coupled. In the illustrated example, the air spring mounting brackets **108** are integrated with the rest of the associated mounting arrangement, including the rear plate **52**, the front plate **54** and the spindle attachment bracket **62**. As best illustrated in FIG. **13**, each air spring assembly **22** includes a rolling lobe-style air spring **110** including an air bladder **112**, an internal lobe member **114** and a top plate **116**. A mounting plate **118** is secured to the lobe member **114** via a plurality of mechanical fasteners **120**, with the mounting plate **118** being secured to the air spring mounting brackets **108** by a plurality of mechanical fasteners such as bolts **122**. The top plate **116** is secured to an upper mounting plate **124** by a plurality of mechanical fasteners **126**. The upper mounting plate **124** is attached to a corresponding vehicle frame rail **14**. As best illustrated in FIG. **14**, the mounting arrangements **50** are located and configured such that the air spring assemblies **22** are inwardly inclined from the mounting assemblies **50** towards the vehicle frame rails **14** at an angle α, thereby resulting in a lower spring rate and reducing the interaction between the suspension and chassis and improving the control in a vehicle jounce event. Further, the incline of the spring assemblies **22** reduces the overall travel thereof, thereby allow use of rolling-lobe type air springs and reducing the overall cost. Preferably, angle α is between 30° and 45° from vertical, and more preferably between 30° and 35° from vertical, thereby resulting in a natural frequency for the vertical displacement or vibrations of the suspension assembly of less than or equal to about 3 Hz, and more preferably of between about 1 Hz and 2 Hz.

The outwardly-sweeping configuration of the trailing arms **16**, **18** (FIG. **12**B) in conjunction with the configuration and construction of the mounting arrangements **50**, provides for attachment of the trailing arms **16**, **18**, the spindles **90**, and the air spring assemblies **22** in close proximity to one another and in close proximity to the ends of the axle member **20**. Preferably, the distance X between the center point of the connection of the trailing arms **16**, **18** with the mounting arrangement **50** and the center point of the connection of the spindle **90** with the mounting arrangement **50** is less than or equal to about 6 inches, the distance Y between the center point of the connection between the spindle **90** with the mounting arrangement **50** and the center point of the connection between the air spring assembly **22** with the mounting arrangement **50** is less than or equal to about 14 inches, and the total length Z of the mounting arrangement **50** is less than or equal to about 20 inches.

As best illustrated in FIGS. **3**A and **3**B, the vehicle suspension assembly **10** is vertically adjustable. Specifically, the axle assembly **20** is movable from a lowered position A, wherein the tires **104** contact a ground surface, thereby assisting and supporting the load of the vehicle, and a raised position B, wherein the tires **104** are spaced from the ground surface, thereby reducing tire wear and fuel consumption. The vehicle suspension assembly **10** includes a pair of lift arrangements **120** operably coupled with the associated upper trailing arms **16** and mounting brackets **12**. Each lift arrangement **120** includes a dual diaphragm chamber assembly **122** (FIGS. **15**A-FIG. **16**) including first diaphragm chamber **124** and a second diaphragm chamber **126**. Each diaphragm chamber **124**, **126** includes a housing **128** divided into an upper chamber **130** and a lower chamber **132** by a deformable diaphragm **134** and a push plate **136**, wherein the upper chamber **130** may be pressurized via an air inlet **138**. Each push plate **136** is secured to a push rod **140** such that the push rods **140** are each forced in a direction **142** as the upper chamber **138** is pressurized. It is noted that in the illustrated example, the longitudinal axis **146** of each of the push rods **140** are aligned with one another. It is further noted that the dual push rods **140** may be replaced by a single push rod that extends through both the first diaphragm chamber **124** and the second diaphragm chamber **126**. The diaphragm chamber assembly **122** is attached to a corresponding upper trailing arm **16** by a lift bracket **148**, while the push rod **140** associated with the second diaphragm chamber **126** is pivotably coupled to an associated mounting bracket **12** by a push rod plate **150** that is fixedly coupled to the mounting bracket **12**, and a clevis arrangement **152** that is attached to the end of the push rod **140** of the second diaphragm chamber **126** and pivotably coupled to the push rod plate **150**. It is noted that the configuration of the diaphragm chamber assembly **122** results in a beveling of the force exerted on the associated push rods **150** while maintaining a reduced overall plan area required to house or position the diaphragm chamber assembly **122** within the overall vehicle suspension assembly **10**.

The vehicle suspension assembly **10** further comprises a self-steer assembly which pivots the spindles **90** and the tires **104** between an inline orientation C, as illustrated in FIG. **4**A, and a turning orientation B, as illustrated in FIG. **4**B. In the illustrated example, the steering assembly **160** includes a tie rod **162** pivotably coupled to spindle arms **164** (FIG. **14**) associated with each spindle **90**. The steering assembly **160** further includes a pair of damper assemblies **166** pivotably secured to the spindle arms **164** and the axle **58** via a pair of mounting brackets **170** (FIG. **2**).

In the foregoing description it will be readily appreciated by those skilled in the art that modifications may be made to the invention without departing from the concepts as disclosed herein. Such modifications are to be considered as included in the following claims, unless these claims by their express language state otherwise.

The invention claimed is:

1. A vehicle suspension assembly, comprising:

an axle member having a first end and a second end;

a first mounting bracket adapted to couple to a vehicle frame assembly;

a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the axle member;

a second mounting bracket adapted to couple to the vehicle frame assembly;

a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the axle member;

an integral, one-piece first mounting arrangement coupled to the first end of the axle member, wherein the first

mounting arrangement couples the first end of the axle member to a first spindle assembly, and wherein the first mounting arrangement couples a first air spring to the first end of the axle member such that the first air spring is adapted to extend between the first end of the axle member and the vehicle frame assembly; and

an integral, one-piece second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement couples the second end of the axle member to a second spindle assembly, and wherein the second mounting arrangement couples a second air spring to the second end of the axle member such that the second air spring is adapted to extend between the second end of the axle member and the vehicle frame assembly.

2. A vehicle suspension assembly of claim **1**, wherein the second end of the first trailing beam is located outboard of the first end of the first trailing beam, and wherein the second end of the second trailing beam is located outboard of the first end of the second trailing beam.

3. A vehicle suspension assembly of claim **1**, wherein the first mounting arrangement pivotably couples the second end of the first trailing arm to the first end of the axle member, and wherein the second mounting arrangement pivotably couples the second end of the second trailing arm to the second end of the axle member.

4. The vehicle suspension assembly of claim **1**, wherein the first mounting arrangement couples the first air spring assembly to the first end of the axle member such that a longitudinal axis of the first air spring assembly is inwardly angled from the first mounting arrangement.

5. The vehicle suspension assembly of claim **1**, wherein the first mounting arrangement includes a recess that receives a first bearing assembly therein, and wherein the first bearing assembly couples the first spindle to the first end of the axle member.

6. The vehicle suspension assembly of claim **5**, wherein the first bearing assembly extends at least partial vertically above the first end of the axle member.

7. The vehicle suspension assembly of claim **1**, further comprising:

a third trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the axle member; and

a fourth trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the axle member.

8. The vehicle suspension assembly of claim **7**, wherein the second end of the third trailing arm is located outboard of the first end of the third trailing arm, and wherein the second trailing end of the fourth trailing arm is located outboard of the first end of the fourth trailing arm.

9. The vehicle suspension assembly of claim **1**, further comprising:

a lift arrangement operably coupled with at least one of the first trailing arm and the second trailing arm, and adapted to move the axle member between a first vertical position, wherein a tire coupled to one of the ends of the axle member contacts a ground surface, and a second vertical position, wherein the tire is spaced from the ground surface.

10. The vehicle suspension assembly of claim **1**, further comprising:

a steering arrangement operably coupled with at least a select one of the first and second spindle assemblies, and adapted to move a tire coupled to one of the spindle assemblies between a first position defining a first direction of travel, and a second position defining a second direction of travel that is different than the first direction of travel.

11. The vehicle suspension assembly of claim **1**, wherein the integrated first mounting arrangement comprises a plurality of individual components welded to one another.

12. A vehicle suspension assembly, comprising:

an axle member having a first end and a second end;

a first mounting bracket adapted to couple to a vehicle frame assembly;

a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end;

a second mounting bracket adapted to couple to the vehicle frame assembly;

a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end;

an integrated first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement couples the first end of the axle member to a first spindle assembly, and wherein the first mounting arrangement couples a first air spring to the first end of the axle member such that the first air spring is adapted to extend between the first end of the axle member and the vehicle frame assembly, wherein the first mounting arrangement couples the second end of the first trailing arm to the first end of the axle member at a first location, the first spindle assembly to the first end of the axle member at a second location, and the first air spring to the first end of the axle member at a third location, and wherein a maximum distance between any one of the first location, the second location and the third location is less than or equal to about 14 inches; and

an integrated second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement couples the second end of the axle member to a second spindle assembly, and wherein the second mounting arrangement couples a second air spring to the second end of the axle member such that the second air spring is adapted to extend between the second end of the axle member and the vehicle frame assembly, wherein the second mounting arrangement couples the second end of the second trailing arm to the second end of the axle member at a fourth location, the second spindle assembly to the second end of the axle member at a fifth location, and the second air spring to the second end of the axle member at a sixth location, and wherein a maximum distance between any one of the fourth location, the fifth location and the sixth location is less than or equal to about 14 inches.

13. A vehicle suspension assembly of claim **12**, wherein the second end of the first trailing beam is located outboard of the first end of the first trailing beam, and wherein the second end of the second trailing beam is located outboard of the first end of the second trailing beam.

14. The vehicle suspension assembly of claim **12**, wherein the first mounting arrangement has a total length of less than or equal to about 20 inches.

15. The vehicle suspension assembly of claim **12**, wherein the first location is located outboard of the third location and the fourth location is located outboard of the sixth location.

16. The vehicle suspension assembly of claim **12**, wherein the first mounting arrangement couples the first air spring assembly to the first end of the axle member such that a longitudinal axis of the first air spring assembly is inwardly angled from the first mounting arrangement.

17. The vehicle suspension assembly of claim 12, wherein the first mounting arrangement includes a recess that receives a first bearing assembly therein, and wherein the first bearing assembly couples the first spindle to the first end of the axle member.

18. The vehicle suspension assembly of claim 17, wherein the first bearing assembly extends at least partial vertically above the first end of the axle member.

19. The vehicle suspension assembly of claim 12, further comprising:

a third trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end pivotably coupled to the axle member by the first mounting arrangement; and

a fourth trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end pivotably coupled to the axle member by the second mounting arrangement.

20. The vehicle suspension assembly of claim 12, further comprising:

a lift arrangement operably coupled with at least one of the first trailing arm and the second trailing arm, and adapted to move the axle member between a first vertical position, wherein a tire coupled to one of the ends of the axle member contacts a ground surface, and a second vertical position, wherein the tire is spaced from the ground surface.

21. The vehicle suspension assembly of claim 12, further comprising:

a steering arrangement operably coupled with at least a select one of the first and second spindle assemblies, and adapted to move a tire coupled to one of the spindle assemblies between a first position defining a first direction of travel, and a second position defining a second direction of travel that is different than the first direction of travel.

22. The vehicle suspension assembly of claim 12, wherein the first mounting arrangement is an integral, single-piece, and wherein the second mounting arrangement is an integral, single-piece.

23. The vehicle suspension assembly of claim 22, wherein the integrated first mounting arrangement comprises a plurality of individual components welded to one another.

24. A vehicle suspension assembly, comprising:

an axle member having a first end and a second end;

a first mounting bracket adapted to couple to a vehicle frame assembly;

a first trailing arm having a first end pivotably coupled to the first mounting bracket, and a second end;

a second mounting bracket adapted to couple to the vehicle frame assembly;

a second trailing arm having a first end pivotably coupled to the second mounting bracket, and a second end;

an integrated first mounting arrangement coupled to the first end of the axle member, wherein the first mounting arrangement couples the first end of the axle member to the second end of the first trailing arm, a first spindle assembly, and a first air spring such that the first air spring is adapted to extend between the first end of the axle member and the vehicle frame assembly, and wherein the first mounting arrangement has a total length of less than or equal to about 20 inches; and

an integrated second mounting arrangement coupled to the second end of the axle member, wherein the second mounting arrangement couples the second end of the axle member to the second end of the second trailing arm, a second spindle assembly, and a second air spring such that the second air spring is adapted to extend between the second end of the axle member and the vehicle frame assembly, and wherein the second mounting arrangement has a total length of less than or equal to about 20 inches.

* * * * *